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Pharos — A Chopper Spectrometer for Inelastic-Neutron-Scattering Studies of Excitations in Materials

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The Pharos spectrometer (Fig. 1) has been a part of the Los Alamos Neutron Science Center (LANSCE) user program for nearly a decade. Originally, the instrument possessed only a small-scattering-angle flight path used primarily for neutron Brillouin scattering studies.[1] However, in the last year, a major upgrade of Pharos was completed, adding 317 new position-sensitive detectors (PSDs) at large scattering angles (for a total of 392), new data-acquisition system hardware and software, a more reliable Fermi chopper system, a new time-zero (T_0) chopper control system, and a new vacuum system. These upgrades have expanded the scope of scientific problems that Pharos can address and have improved the reliability and efficiency of the instrument. In addition, the suite of Pharos sample-environment devices are presently being expanded to provide high temperatures (up to 1500°C), large magnetic fields (up to 11 T), and high pressures (up to 10 kbar) and include a three-axis, single-crystal rotation stage. Pharos can now perform a full range of inelastic-neutron-scattering measurements, including those of phonon and spin-wave dispersions in single crystals; phonon and spin-wave densities of states; crystal-field, spin-orbit, and other electronic excitations; and neutron Brillouin scattering.

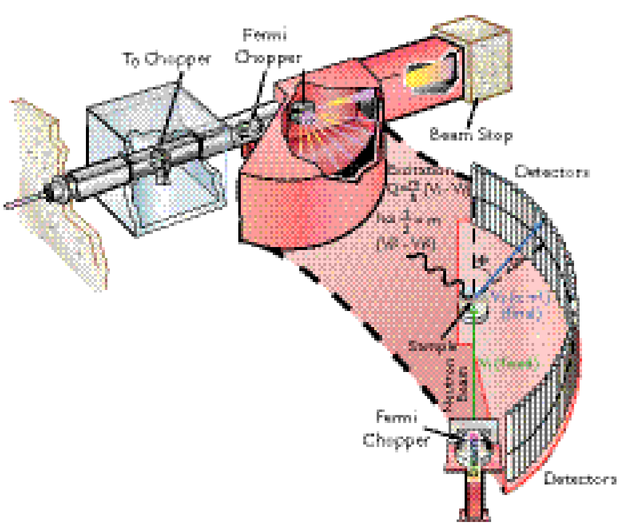

Fig. 1. Rendering of the Pharos instrument.

Pharos Specifications

Moderator and beam transport. Pharos is viewed at a 15° angle by a 12- x 12-cm^2 ambient high-resolution water moderator poisoned with gadolinium at a depth of 1.5 cm. The beam is reduced down to a 5- x 7.5-cm^2 area at the sample position (at 20 m from the moderator) by continuous beam scraping.

Fermi choppers. A Fermi chopper is used to obtain a monochromated incident beam. The efficiency of transmitting neutrons through the Fermi chopper depends on its rotational frequency, body radius, and slit radius and on the neutron incident energy. Pharos has three different Fermi choppers to provide different incident energies from ~ 10 to 1,000 meV (see Table 1).

Detector and data-acquisition systems. Pharos is outfitted with 392 ^{3}He-filled PSDs that are 1 in. in diameter. This detector bank contains 376 tubes

Table 1. Pharos specifications.

Energy transfer resolution	$\Delta E/Ei$ = 1% to 4%
Moderator	Chilled water at 283 K (1.5-cm Gd-poisoning depth)
Beam size	5 cm x 7.5 cm
Sample distance from moderator	20 m
Fermi chopper - Distance from moderator - Frequency - Diameter - Optimal energy at 600 Hz - Slit spacing - Slit curvature - Phasing error to alternating-current line (FWHM) - Manufacturer	 18 m 60 Hz to 600 Hz 10 cm 100, 300, and 1,000 meV 3.6 mm, 2.1 mm, and 1.0 mm 0.58 m, 1.0 m, and 1.83 m ~ 1.5 µs Revolve Magnetic Bearings, Inc.
T_0 chopper - Distance from moderator - Material - Frequency	 14 m Inconel (341 kg) 10 to 60 Hz
Detectors - Distance from moderator - 376 position-sensitive detectors - 16 position-sensitive detectors - Scattering-angle coverage - Solid-angle coverage - Positional resolution (FWHM) - Manufacturer	 24 m (low angle movable to 30 m) 1 in. diam., 1 m long 1 in. diam., 16 in. long, above and below direct beam 1.5° to 145° 0.7 sr < 1 cm Reuter-Stokes, Inc.

that are 1 m long at a distance of 4 m from the sample. These tubes continuously cover horizontal scattering angles from -10° to -1.5° and 1.5° to 145° and vertical angles from -7° to +7°. The other 16 detectors are 16-in.-long PSDs (above and below the direct beam). All of these detectors have a position sensitivity better than 1 cm, but they are typically divided into 1-in. elements for data collection. (There are ~ 15,000 detector pixel elements of 1 x 1 in^2.) We typically work with several thousand time-of-flight channels of 1 to 3 µs in duration over a range of several milliseconds. Thus, the instrument contains an astounding 50 million individual elements in each histogram.

Background suppression. Due to the monochromatic beam and the intrinsic weakness of neutron inelastic scattering (which is several orders of magnitude less than elastic Bragg scattering), the suppression of external sources of neutron and γ-ray background is extremely important. The T_0 chopper attenuates fast neutrons and γ-rays from the prompt pulse by rotating a large Inconel chopper into the beam precisely at the time T_0. These fast neutrons and γ-rays are emitted from the target. Without the T_0 chopper, fast neutrons would thermalize in the shielding and leak out over time, contributing to a significant background signal. The Pharos T_0 chopper can rotate up to 60 Hz in multiples of 20 Hz. To minimize air scattering in the secondary flight path, the entire secondary spectrometer vessel (1,100 m^3) is evacuated down to 10^{-3} torr. A separate smaller sample chamber can reach cryogenic vacuum levels (10^{-8} torr). In the near future, we plan to install a radial collimation system in the secondary flight path to reduce the scattering from bulky sample-environment devices (e.g., the 11-T cryomagnet and gas-pressure cells).

Acknowledgements

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References

1. R.A. Robinson et al., in *Proceedings of the 10th Meeting of the International Collaboration on Advanced Neutron Sources, Institute of Physics Conference Series* **97**, 403 (1989).

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